Special issue in honour of Vladimir S. Rabinovich

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EDITORIAL

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This issue of the Complex Variables and Elliptic Equations is dedicated to the prominent mathematician, doctor of physical-mathematical sciences, professor of the National Polytechnical Institute of Mexico, our friend and colleague, member of the editorial board of the journal Vladimir Samuilovich Rabinovich, on the occasion of his 80-th birth anniversary.

Vladimir Rabinovich was born in Kiev on 2 September 1940, where his childhood passed. In the beginning of the Nazi invasion of USSR in 1941, when many people were evacuated from the Western regions to the interior parts of the country, his family went from Kiev to the city of Kuibyshev on Volga river (the city of Samara before 1935 and after 1991). They returned to Kiev in 1947.

In 1961 Vladimir became a student of the Department of Mechanics and Mathematics of the Rostov State University (today known as Southern Federal University, Russian Federation), where he came a long way from being a student to becoming a leading professor in the department of algebra and discrete mathematics. Despite still being a PhD student at the department of differential and integral equations under the supervision of professor V. A. Kakichev, in essence, he had already become a part of the famous scientific school of professor I. B. Simonenko as one of the key participants of the professor's seminar. In 1972, he became a lecturer for the department of algebra and discrete mathematics, created by I.B. Simonenko. It was there that V.S. Rabinovich grew professionally to become a true scientist, as well as a teacher. He started teaching there, and after the defense of his doctoral thesis, "The limit operator method in the

question of the solvability of pseudo-differential and convolution equations", in 1993, became a full professor in this department.

The main course V.S. Rabinovich taught for many years was a course on mathematical analysis for applied mathematicians, which he taught together with his own teacher, I. B. Simonenko, as well as a later course on algebra and geometry for students of applied mathematics and mechanics, which he taught before his departure to Mexico. Unfortunately, Vladimir Rabinovich did not write a textbook or training manual on this subject. One of the authors of this article still has his own notes, taken during those classes. Even through them one can see how close was that course to the "necessary and sufficient".

In the department of algebra and discrete mathematics of Rostov University, Vladimir Rabinovich created his own scientific school on the subject of the theory of pseudo-differential operators, raised and prepared a whole pleiad of students, which include A. Babayan, L. Doktorsky, V. Kryakvin, B. Lange, S. Levendorsky, M. Lorenz, Y. Lutsky, O. Obrezanova, L. Urazhdina, among others. Vladimir Rabinovich is still actively working on preparing scientific cadres in the National Polytechnical Institute of Mexico, where he has been a professor for more than 20 years. In Mexico, he has guided 6 philosopy doctors and 22 masters of science.

Vladimir Rabinovich is a wonderful friend and team player, which seldom happens amongst mathematicians. During his years working at RSU he built a wide circle of scientific and human interaction, which undoubtedly included and still includes his older friends and colleagues: his teacher I.B. Simonenko, academician I. I. Vorovich, professor Y. A. Ustinov, his peers and occassional co-authors – S. Samko, N. Karapetyants, A. Zadorozhny, A. Heifiz, his younger colleagues in the department and the scientific seminar, such as V. Pilidi, V. Semenyuta, A. Sazonov, Y. Erusalimskiy, S. Grudsky, A. Kozak, V. Deundiak, C. Mikhalkovich, M. Abramyan. Something that is characteristic of Vladimir Rabinovich is that his scientific contacts usually grow further to become a sort of relationship that can be best described by the word "friendship". We will just mention some of his scientific colleagues and friends: Y. Karlovich, G. Burlak, N. Vasilevski, A. Pankov, P. Kuchment, V. Kravchenko, B. Silbermann, S. Roch, I. Spitkovsky, A. Soldatov, A. Kilbas, R. Duduchava, E. Shargorodsky, V. Burenkov, T. Suslina, A. Nakhushev, A. Boettcher, B.-W. Schulze, L. Rodino, N. Tarkhanov and others.

While working in Mexico, Vladimir Rabinovich doesn't interrupt his scientific contact with his alma mater, delivering yearly presentations on the seminars of the department, reviewing papers by his colleagues, working actively in the editorial board of the journal "Notices of the universities. Northern Caucasus Region. Natural sciences". Vladimir Rabinovich is a foreign member of the Dissertation council of physical-mathematical sciences in the Southern Federal University.

We can't avoid mentioning the fact that V. S. Rabinovich has not only achieved great heights in mathematics, where the expression is used in a metaphorical way, but also factually. As an aficionado of mountaineering and alpinism, he has visited many peaks and mountain passes of the Caucasian range, Pamir and Tian Shan. For many years he was also one of the most passionate participants of the Sunday morning soccer games between mathematicians and mechanics of the Rostov University on the left bank of the Don river.

We congratulate Vladimir Rabinovich for the eightieth year since his birth and sincerely wish him health, prosperity and creativity. We gladly note that he is welcoming this anniversary in the prime of his life, still opening up new facets of his mathematical talent. Witnesses to this are his recent papers published in leading scientific journals.

Below we give a far from being a complete review of main scientific results of Vladimir Rabinovich. The first work was published in 1967. In it the question on the closed-form solution of multidimensional Wiener-Hopf equations for cones was considered. In 1968 it was followed by a publication on the generalization onto weighted Lebesgue spaces of estimates for shift-invariant operators. Papers of 1967–1969 dedicated to solvability and Fredholmness

of multidimensional Wiener-Hopf equations in unbounded n-dimensional domains having conical structure at infinity naturally led to the defense of the PhD thesis in 1969. It is worth mentioning that Vladimir got interested and obtained remarkable results in the field of pseudodifferential operators which has been actively developing at that time.

For the first time he considered problems on solvability and Fredholmness of boundary value problems for certain classes of elliptic pseudodifferential operators in domains with unbounded boundaries having conical structure at infinity and obtained a-priori estimates for their solutions. During several years which followed the defense of the PhD thesis there appeared Vladimir's publications presenting interesting results for quasi-elliptic pseudodifferential operators and on solvability of Cauchy and Goursat problems for parabolic pseudodifferential equations (1971–1979 and later on), on solvability difference-differential equations (1978–1985 and later on), on Fredholmness of elliptic pseudodifferential operators and associated boundary value problems on noncompact manifolds (papers of 1971–1979).

Resuming I. B. Simonenko's research on multidimensional convolution type operators, in the work of 1974 for such operators in a cone there have been obtained necessary and sufficient conditions of Fredholmness in the L_p space with the exponential weight. These conditions consist in the requirement of nondegeneracy of the operator symbol on the frame of some tubular domain associated with the weight and the cone. The key ideas contained in that work gave rise to subsequent studies of other classes of operators in different functional spaces with exponential weights. In the one-dimensional case the corresponding result belongs to I. Ts. Gokhberg and M. G. Krein.

In the work of 1982 and 1983 the algebras generated by pseudo-differential operators, multiplication operators on almost periodic functions and shift operators were considered, then jointly with the PhD student R. Babadzhanyan in 1985–1987 the systems of difference-integral equations in half-space were studied, on the basis of I. B. Simonenko's local principle (modified by V. S. Pilidi) and conditions of their Fredholmness were obtained.

The following important scientific results of V. S. Rabinovich are connected with the method of limit operators developed by him. Although the idea of limit operators, apparently, for the first time appeared in the article of J. Favard in 1927 on the existence of solutions for ordinary differential equations with almost periodic coefficients, and further the idea of using limit operators was applied by E. M. Mukhamadiev to describe the solvability of elliptic partial differential equations (1981), but V. S. Rabinovich first generalized this approach by creating a largely general and even abstract scheme of the limit operator method for studying the solvability (Fredholmness) of operators from different classes.

The beginning in the development and use of the method of limit operators was made by V. S. Rabinovich in the works 1985 and 1986, performed jointly with the graduate student B. Lange. Further advances led to the study of the solvability (Fredholmness) of pseudo-differential operators of several general classes in different scales of functional spaces, discrete and continuous operators of convolution type, general boundary value problems on manifolds with an edge and having a conic structure at infinity, etc. (see papers of 1988, 1992, 1993, 1994, 1998, 1999, 2001–2003 and more recent ones, e.g. papers of 2015). In 1993 he defended his doctoral thesis "The method of limit operators in solvability of pseudo-differential equations and convolution equations". As can be seen from the list of publications, the defense of this second doctoral degree thesis was only a step to further research, discoveries and achievements.

During a short stay in Portugal V. S. Rabinovich wrote and published a small but very capacious textbook: "An Introductory Course on Pseudodifferential Operators", Instituto Superior Tecnico. Textos de Matematica. Centro de Matematica Aplicada, Lisbon, 1998.

During the same period, work was continued in collaboration with German mathematicians S. Roch and B. Silbermann (begun with an article in 1998). The result of their joint work was the

monograph "Limit Operators and Their Applications in Operator Theory" published in 2004 by Birkhäuser Verlag. In the monograph, a general theory of the limit operator method is presented, with effective applications to various problems of discrete and continuous operators, including convolution type operators, pseudodifferential operators, singular integral operators on Carleson curves. This monograph also proposes a variant of the projective method for solving the corresponding equations.

It should be noted that the ideas and methods proposed in the mentioned monograph are intensively used and developed at present in the works of many American, German and French mathematicians. The studies related to the limit operators were continued by the co-authors in 2004–2010, including applications to the problems of mathematical physics and construction of effective numerical algorithms for solving these problems.

Total co-authored with S. Roch and/or B. Silbermann, V.S. Rabinovich published about 30 works.

Even the titles of the published works testify to the versatility of V. S. Rabinovich's mathematical interests, so it is difficult even to mention all the results obtained by him. Nevertheless, let us continue by paying attention to the works devoted to algebras of singular integral operators defined on a class of Carleson curves. In the papers of 1991–1996, it was shown that Mellin pseudo-differential operators with symbols from suitable classes are an effective tool for studying singular integral operators on contours with singularities of the logarithmic curl type, their full-scale study was done, properties of Mellin pseudo-differential operators and singular integral operators were studied. These studies were continued in co-authorship with A. Böttcher (Germany) and Yu. I. Karlovich (Mexico) in 1996, 1998, 2000, 2001, where the spectra of singular integral operators on compound Carleson curves with singularities, pseudodifferential Mellin operators and singular integral operators with weights satisfying Muckenhoupt's condition, and other related problems were considered.

Another direction of research in which Vladimir Rabinovich made a significant contribution is directly related to the modern theory of spaces of functions with variable orders and exponents. In joint works with S. G. Samko in 1997, 2007, 2008, 2011, and 2012, singular integral operators on compound Carleson curves in Lebesgue spaces with variable exponents and in weighted Hölder spaces were studied, as well as pseudodifferential operators in Lebesgue spaces with variable exponents. And in the works of 2017 and 2018, in collaboration with V. Kryakvin, pseudodifferential operators of variable order in scales of Hölder-Zygmund and Besov spaces with variable smoothness exponents were considered, and sufficient compactness and Fredholmness conditions were obtained, including those in weighted spaces with superpower behaviour at infinity.

A remarkable team (V. Rabinovich, B.-W. Schulze (Germany), N. Tarkhanov (Germany)) gathered to study in six papers of 2000, 2001, 2002 and 2004 the solvability and properties of solutions of boundary value problems in domains with non Lipschitz singularities on the boundary as well as singular integral operators on such domains.

Another research line, which was initiated in the work of 1974 (continued together with the PhD student Ya. Lutsky) is devoted to the study of pseudodifferential operators in the spaces of distributions of exponential behaviour at infinity (1976, 1977, 1978), and after some time in the joint works with Ya. Lutsky in 2008 and 2009, where they investigated the invertibility of parabolic pseudo-differential operators with rapidly growing symbols and obtained estimates of exponential behaviour of solutions of pseudo-differential operators with growing and discontinuous symbols.

It should be said that in the papers of 1974 and 1978 the class of pseudo-differential operators with analytic symbols in the tubular domain $R^n + i\Omega$ in $\mathbb{C}^n$ was introduced. In those publications and in the subsequent series of works 1997, 2004, 2006, 2008, 2009, 2011, the last (maybe not the last anymore) of which refer to 2017–2018, properties of these operators were

studied, strong results were obtained on the behaviour of solutions of differential and elliptic pseudodifferential equations in the neighbourhood of the singularity of the coefficients and at infinity, boundedness theorems were proved in many important scales of spaces, Fredholmness in appropriate spaces with exponential weights was studied, exponential decay of solutions of elliptic pseudodifferential equations at infinity was proved. Applications of the obtained results to the study of the exponential decay of the eigenfunctions of the Schrödinger, Dirac and other equations were also presented in the papers of 2004 and 2008–2010.

V. S. Rabinovich's scientific interests extend to broad applied fields, including propagation of acoustic and electromagnetic waves in different media and from different sources, scattering problems, quantum physics problems, and many others. In 1989, 1990, 1993, 1996 and 1998 jointly with S. M. Grudsky, S. Edelstein, V. Yanover and other researchers of Rostov State University and O. A. Obrezanova, a PhD student, the sound propagation at large distances in the ocean from a moving source under different conditions was studied. Asymptotic approximations for acoustic fields in stratified waveguides were obtained. These and related studies were continued in 2003, 2005, 2007, 2009, 2010 in Mexico with Mexican colleagues and students.

Publications of the last decade show that Vladimir Samuilovich was fascinated by mathematical problems arising in different fields of modern physics, including quantum physics, electromagnetic theory and acoustics. One can, for example, note the work of 2018 on the transfer matrix in quantum waveguides with impurities, or the works of 2017–2019 on the study of self-adjointness and essential spectrum of Schrödinger operators with interactions on unbounded hypersurfaces. Works, including those performed in this period together with V. Kravchenko, G. Burlak and their Mexican colleagues on electromagnetic fields in different media generated by moving sources, in particular, on Cherenkov radiation, etc., confirm the stated thesis. In these fields of research, not only theoretical results are obtained, they are brought to "number": the 2017 work is devoted to numerical estimates of the acoustic field in the ocean with a moving source in the air, and the 2019 work allows numerical investigation of the discrete spectrum of the one-dimensional Schrödinger operator with point interactions.

Vladimir Samuilovich's scientific productivity as a researcher is amazing. In this review, we have managed to touch upon only part of his "scientific product". His friends wish him to keep a good sportive form, and keep in general a keen interest to mathematics and social life for many and many years ahead.

Acknowledgements

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